Chapter 5
Population Structure

Key Questions:

a) *What were the historical populations of steelhead in Washington?*
b) *How have anthropogenic factors such as hatchery programs and habitat modifications affected population structure?*
c) *What is the source of broodstock for hatchery programs in each region?*

5.1 Introduction

This chapter presents a listing of extant and extinct naturally spawning populations of steelhead in Washington, identifies anthropogenic influences on population structure, and summarizes the methods used to identify populations. Current and recent sources of broodstock for hatchery programs are also provided.

5.1.1 Natural Populations

Identification of population structure is a critically important step in the assessment and management of salmonids. Population-specific data often are the basic unit of analysis for assessments of productivity, sustainable fishery exploitation rates, and extinction risk. Failure to correctly identify the underlying population structure of a species aggregation can result in the loss of habitat essential to preserve genetic diversity, the application of fishing exploitation rates that are unsustainable (Hilborn 1985), or the selection of inappropriate broodstock for an artificial production program (Waples 1991; RASP 1992).

When the Washington Department of Fisheries, the Washington Department of Wildlife and the western Washington treaty tribes created the framework for the 1992 Salmon and Steelhead Stock Inventory[1], guidelines for stock identification were developed based on the definition of a stock proposed by Ricker (1972):

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[1] Originally labeled as SASSI in 1992, the acronym was modified to SaSI (Salmonid Stock Inventory) in 1999 to reflect the addition of Dolly Varden and bull trout. SaSI is a standardized, uniform approach to identifying and monitoring the status of Washington's salmonid fish stocks. The inventory is a compilation of data on all wild stocks and a scientific determination of each stock's status as: *healthy, depressed, critical, unknown, or extinct*. SaSI data and status rating is accessible through the web application SalmonScape (see Box 3-1).

"…the term stock is used here to describe the fish spawning in a particular lake or stream (or portion of it) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place at a different season. What constitutes a "substantial degree" is open to discussion and investigation, but I do not mean to exclude *all* exchange of genetic material between stocks, nor is this necessary in order to maintain distinctive stock characteristics that increase an individual's expectation of producing progeny in each local habitat.

In some rivers a number of stocks can be grouped together on the basis of similarity of migration times. The word *run* will be used for such groupings. Thus we may speak of a fall run of chinook or steelhead for example. Each run may comprise a considerable number of stocks."

McElhany et al. (2000) also built on Ricker's concept to define populations for the purpose of recovery planning. The phrase a "substantial degree" of interbreeding was refined and more clearly defined as "two groups are considered independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame."

In practice, WDFW has found that empirical data are either not available or sufficiently precise to distinguish a stock in the sense of WDF et al. (1993) from a population as defined by McElhany et al. (2000). For consistency with ongoing recovery planning, the term population is used throughout the remainder of this document.

The ESA refers to subspecies and "distinct population segments" (DPSs) as the listable units of biological organization. However, the ESA provides no guidance for identifying these units. Waples (1991) proposed the use of an Evolutionarily Significant Unit (ESU) to identify subspecies and distinct population segments of Pacific salmon and steelhead. An ESU is a population or group of populations within a species that: 1) is substantially reproductively isolated from other populations (or groups of populations) of the same species and; 2) represents an important contribution to the evolutionary legacy of the species as a whole (Waples 1991). NOAA Fisheries formally adopted ESUs as the population units for listing/delisting (NMFS 1991)(Fig. 5-1).

Steelhead ESUs were identified by the NOAA Fisheries steelhead BRT as part of their coastwide reviews of steelhead status (Busby et al. 1996; Good et al. 2005). Individual ESUs were identified based on genetic and ecological evidence for reproductive isolation, including the presence of natural barriers that could serve to isolate populations. Genetic and ecological distinctiveness were assessed based on information about migration and spawn timing, life history patterns, zoogeography and hydrology.

NOAA Fisheries subsequently decided to use distinct population segments, rather than ESUs, for listing determinations because the ESA jurisdictional responsibility for *O. mykiss* is shared with the U.S. Fish and Wildlife Service (71 FR 834).

This report uses the concept of ESUs to provide a geographic structure above the populations level. We decided to use ESUs because of their biological, rather than administrative, basis but retained sub-regional biological and management groupings as appropriate. We relied on Busby et al. (1996) for descriptions of the geographic extents and factors that influenced the definition of individual ESUs. Recognizing that the ESUs are too coarse for stock assessment, harvest and habitat management, nearly all data have been acquired and organized at the stream or watershed level and grouped into sub-regions (e.g., Hood Canal, Grays Harbor, Willapa Bay).

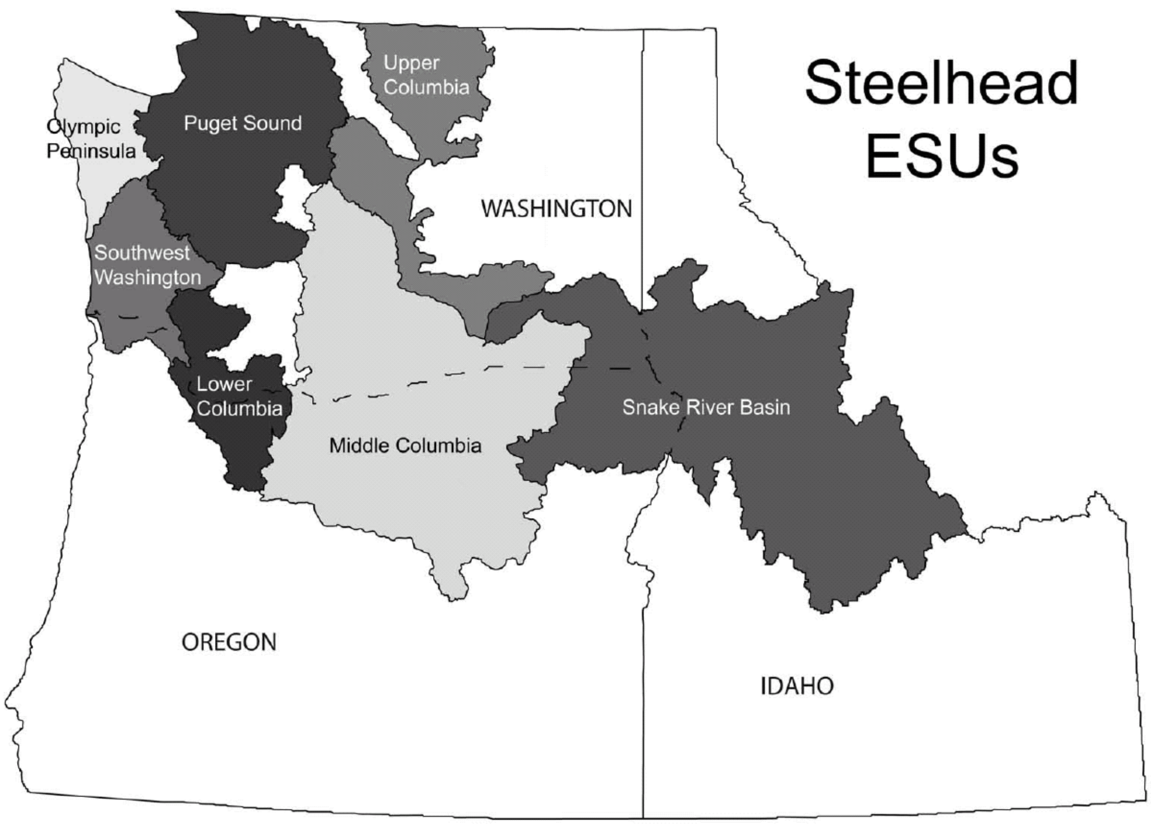
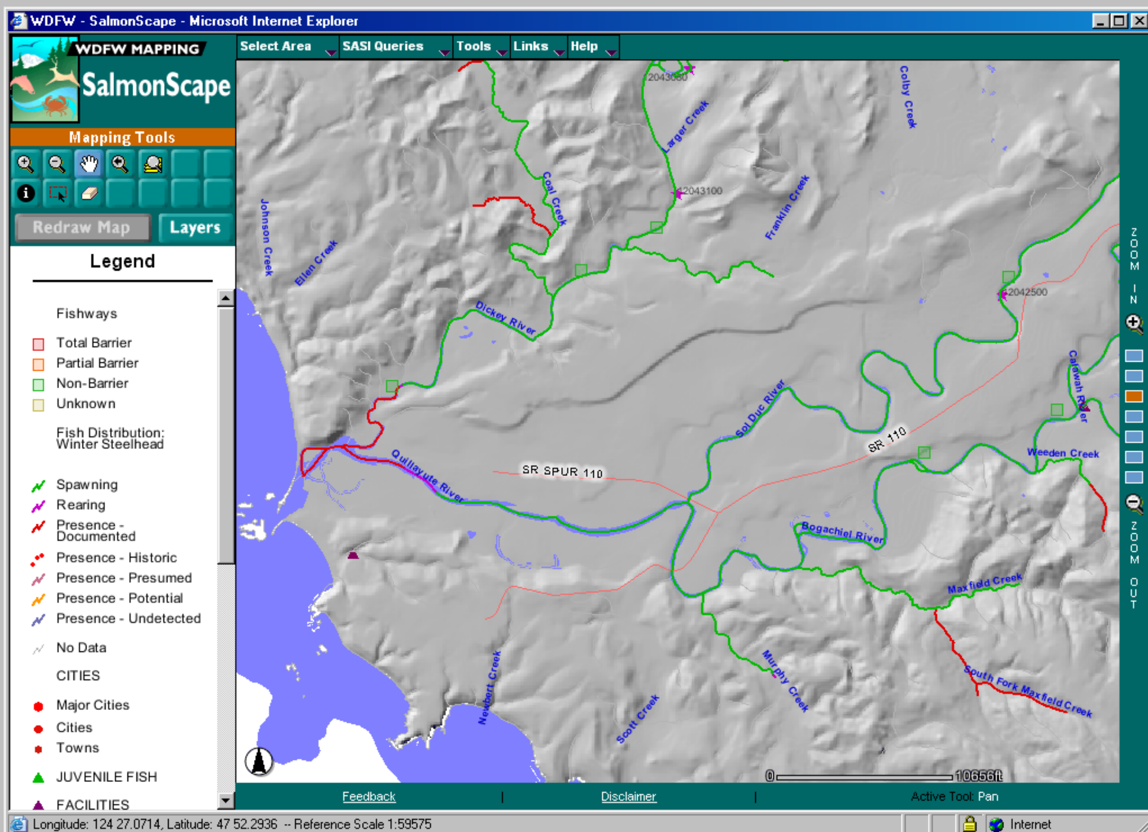


Figure 5-1. Steelhead ESUs all or partially located in Washington State.

Box 5-1. SalmonScape Web Application

A variety of fish and habitat-related information can be viewed on the Web using the WDFW SalmonScape application. SalmonScape supports interactive selection and display of spatial datasets such as steelhead populations, SaSI stock status, fish distribution and use, migration barriers, EDT preservation and restoration priorities (WRIAs 22-28 only), juvenile fish trap sites, and stream habitat attributes. These data can be displayed against many background layers, including administrative boundaries, roads, streams, major public land ownership, township/section lines, shaded relief imagery and orthophotos.

The SalmonScape URL is http://wdfw.wa.gov/mapping/salmonscape/index.html. A screenshot of a typical page featuring winter steelhead distribution and use in the lower Quillayute River appears below.



5.1.2 Hatchery Broodstock

The historical origin and characteristics of the broodstock for artificial production programs are important for at least two reasons. First, gene flow from hatchery-origin steelhead to a natural population, or introgression, may make it difficult to identify historical populations from current genetic or other biological data. Understanding the characteristics of the hatchery-origin steelhead can help explain and clarify confusing or contradictory results. Second, the assessment of an artificial production program is dependent in part on understanding the historical origin and characteristics of the source of broodstock.

5.2 Methods

5.2.1 Historical Populations

Following listing of all Columbia River steelhead under ESA, Technical Recovery Teams (TRTs) under NOAA Fisheries leadership have been convened for the Willamette/Lower Columbia River and the Interior Columbia River basins. One of the initial tasks of each TRT was to identify historical steelhead populations in the Columbia and Snake rivers. The Willamette/Lower Columbia TRT (WLCTRT) focuses on the Upper Willamette (above Willamette Falls) ESU and the Lower Columbia River ESU (Myers et al. 2004). The Interior Columbia Basin TRT (ICTRT) focuses on the Middle Columbia, Snake River and Upper Columbia ESUs (ICTRT 2003).

The approaches taken by the two TRTs to identify historical populations are somewhat different. The WLCTRT has attempted to identify watersheds whose size and habitat characteristics historically were large enough to support viable demographically independent populations (Myers et al. 2004). The information used to do so includes documented historical use, differences in run and/or spawn timing, geographic isolation and basin-specific information about features such as impassable barriers. Geographic isolation was determined using “geographic templates”. The WLCTRT attempted to identify minimum basin areas (geographic templates) needed to support a demographically independent population. Minimum basin area determination was based on examination of the number of extant populations known or thought to be distinct within stream basins of different sizes. The ICTRT identified historically occupied areas, generally located above dams, which once supported anadromous *O. mykiss* and which now have lost the species or support only resident *O. mykiss*.

No systematic effort has been previously made by WDFW to identify historical populations of steelhead in Puget Sound or the Washington coast. SaSI includes all current populations but not extinct stocks unless the extinction has occurred recently and is well documented by state, tribal or other biologists. We reviewed historical records and published studies to identify any additional historical populations that may have been extirpated in the ESUs for which TRTs have not been convened (Puget Sound, Olympic Peninsula, and Southwest Washington).

5.2.2 Extant Native Populations

Genetic analyses from external sources (ICTRT 2003; Myers et al. 2004) and WDFW were used to help identify steelhead populations. WDFW analyses were generally based on 156 collections of juveniles or adults collected from 1993 through 1996 (see Phelps et al. 1994; 1997). These investigators conducted horizontal starch-gel electrophoresis to analyze variation at 56 enzyme-coding loci using over 150 collections of adult or juvenile steelhead from throughout Washington.

Datasets for Puget Sound, coastal Washington and the lower Columbia River populations were re-analyzed for this report (see Appendix 5-A for a complete description of methods). For each of these regions, a consensus dendrogram was constructed to evaluate the certainty of the genetic relationships among the datasets. The consensus dendrogram was constructed by repeating (or bootstrapping) the following steps 1000 times: 1) resample the allelic frequencies in each dataset; 2) compute the pairwise Cavalli-Sforza and Edwards (1967) chord distances between the allelic frequencies for each dataset; and 3) use the Neighbor-Joining (N-J) algorithm to construct a tree by successive clustering of each of the datasets. From the 1000 repetitions, a consensus dendrogram was constructed by selecting the clusters of datasets, or nodes, that occurred most frequently. Nodal bootstrap values represent the number of times the branching to the right of the node occurred in the 1000 trees analyzed. We considered bootstrap values of greater than 65% to indicate supported nodes and have deleted all lower bootstrap values (indicated nodes with little or no statistical support) to simplify the figures. The labeling of in the dendrograms includes an abbreviation of the stream or hatchery (designated by ‘H’) name, the last two digits of the year of collection, and a one-letter code for the adult return time of the population (‘S’ =summer run; ‘W’ = winter run; or ‘B’ = possible mixed collection containing both summer and winter run fish).

5.2.3 Hatchery Broodstock

Information on the origin and characteristics of broodstock used in artificial production programs was obtained from a wide variety of sources. These included staff working in the facilities, historical records, published papers, and other records maintained by

WDFW. Other existing compilations exist for Puget Sound and the Washington Coast (HSRG 2002; 2003; 2004) and the Columbia basin (NMFS 2003; NMFS 2004).

5.3 Results

5.3.1 Puget Sound

Natural Populations

The following description of the Puget Sound ESU is primarily a summary of information from Busby et al. (1996). The Puget Sound ESU includes streams ranging from the Canadian border (Nooksack River basin), south through Puget Sound and Hood Canal, north and west to the Elwha River, which empties into the eastern Strait of Juan de Fuca (Fig. 5-2). The region lies in the rain shadow of the Olympic Mountains and is significantly drier than the Olympic Peninsula to the west. The relatively protected marine environment of Puget Sound provides an opportunity for both juvenile and adult residence time that is not available to high seas-migrating steelhead in the other ESUs. The elongate geometry of the marine basins and embayments also provides for broad variations in tidal currents, sub-basin flushing capacity, and relative stagnation. This can subsequently be expressed as a vulnerability to pollutant concentration that generally increases toward the South Sound region and into the Hood Canal fjord. Populations in British Columbia were excluded on a biological basis because they tend to primarily migrate to marine waters at age three, whereas those in Washington tend to migrate at age two.

Genetic samples have been taken from steelhead collected at 40 locations within the geographic extent of the Puget Sound ESU and allozyme analysis conducted for 56 polymorphic loci (Phelps et al. 1997). Many of the samples were from juveniles and in some cases may have included a mixture of summer steelhead, winter steelhead, and resident *O. mykiss*. The consensus N-J dendogram revealed little geographic structure among the sample groupings and bootstrap support for the groupings was generally poor.

In the absence of informative genetic analysis, we generally relied on the populations identified in WDF et al. (1993). Identification of these populations was based on the geographic isolation of spawning areas and/or the apparent non-overlap of spawn timing (WDF et al. 1993).

We identified 51 populations that historically were present within the Puget Sound ESU (Table 5-1). Two populations, Baker Summer and Chambers Winter, may have been extirpated. The Baker Summer population was likely extirpated after construction of the Baker dams blocked access to spawning areas in the Baker River. The Chambers

PUGET SOUND STEELHEAD ESU

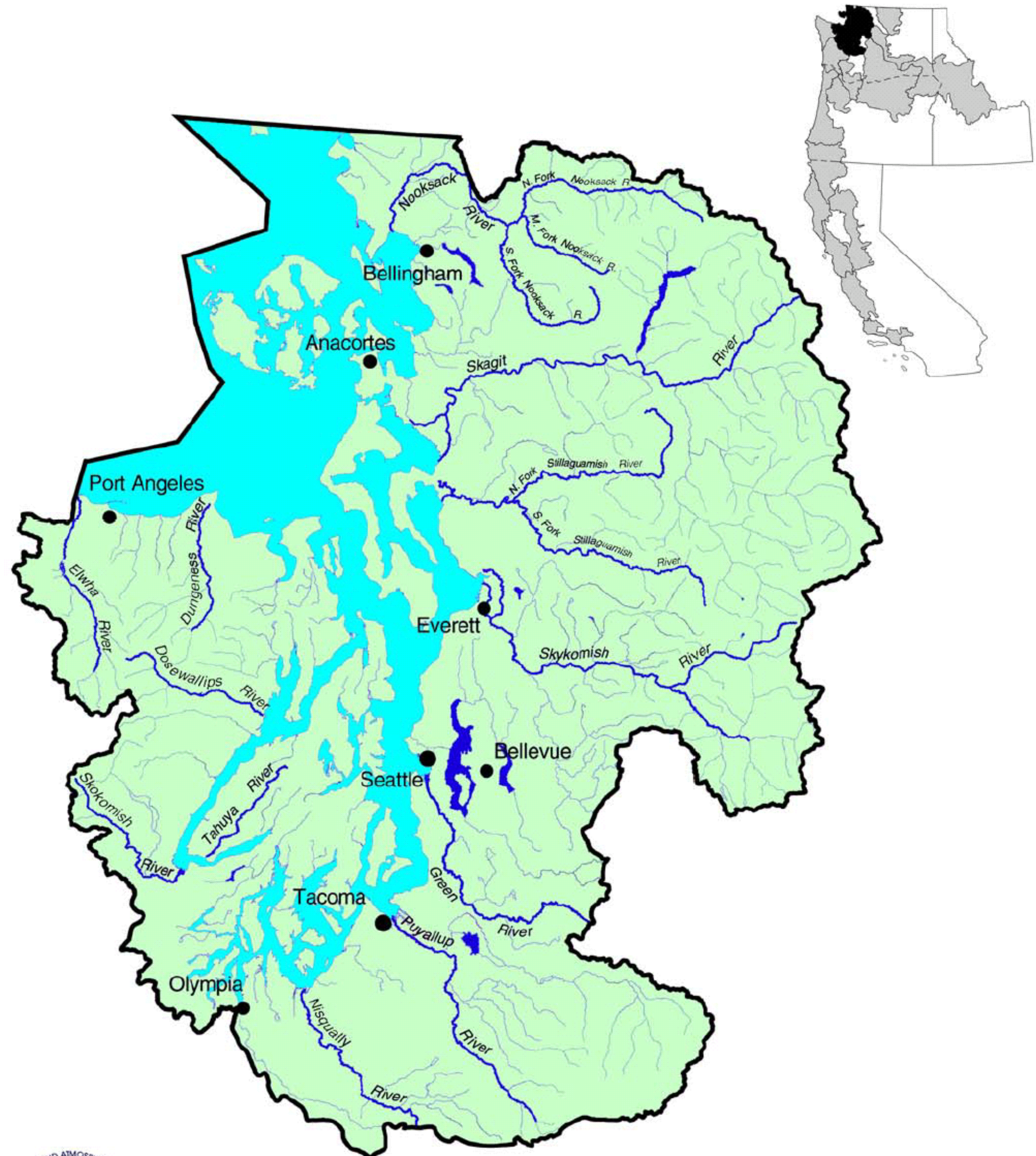


Figure 5-2. Puget Sound ESU map.

Winter population was extirpated, probably as a result of broodstock collection at Chambers Creek and selective breeding at the South Tacoma Hatchery.

Releases of hatchery-origin juveniles may have resulted in the establishment four new populations of steelhead:

> South Fork Stillaguamish Summer. Summer steelhead of Skamamia-origin were introduced into the South Fork Stillaguamish River coincident with the construction of the Granite Falls fish ladder in the mid-1950s. A natural self-sustaining population may now exist, although this is difficult to determine because of the annual release of hatchery-origin steelhead continued through 2002.
>
> South Fork Skykomish Summer. Summer steelhead of Skamamia-origin were introduced into the South Fork Skykomish River coincident with the initiation of a trap-and-haul operation at Sunset Falls in the mid-1950s. Despite the absence of releases of hatchery-origin steelhead into the South Fork Skykomish since 1992, 500-1,200 adults returned to Sunset Fall in each year from 1999 through 2003. Pairwise genotypic differentiation tests indicate significant differentiation among the South Fork Skykomish Sunset Falls population, North Fork Skykomish Summer natural population and Reiter Ponds rearing facility (Skamania-origin). Other measures of genetic similarity (e.g. genetic distance, and F_{ST}) indicate that the Sunset Falls population are more similar to the Reiter Ponds summer hatchery strain than to the indigenous North Fork Skykomish population (Kassler and Hawkins, pers. comm.).
>
> Green Summer. Annual stocking of juvenile summer steelhead of Skamania origin was initiated in 1965. A natural self-sustaining population may now exist, although this is difficult to determine because of the continued introduction of hatchery-origin steelhead. The presence of unmarked steelhead in the catch may be indicative of natural production. An average of 8.7% of the sport and tribal catch of summer steelhead was unmarked in the years 1988 to 2003.
>
> Deschutes Winter. Winter steelhead of Chambers Creek-origin were introduced into the Deschutes River when a fish ladder was installed at Tumwater Falls in 1954. It has been difficult to determine if a naturally self-sustaining population exists because of the continued introduction of hatchery-origin steelhead. It seems unlikely, however, because few unmarked steelhead smolts are captured at a smolt trap operated on the Deschutes River.

Table 5-1. Puget Sound region historical and extant natural steelhead populations.

Historical Population	Extant Population
Nooksack Basin	
Dakota Creek Winter	Dakota Creek Winter
Mainstem/NF Nooksack Winter	Mainstem/NF Nooksack Winter
MF Nooksack Winter	MF Nooksack Winter
SF Nooksack Summer	SF Nooksack Summer
SF Nooksack Winter	SF Nooksack Winter
Samish Winter	Samish Winter
Skagit Basin	
Baker Summer	Potentially Extirpated. Anadromous access to the Baker River lost after construction of the Baker dams. Resident form of *O. mykiss* may remain in the upper watershed.
Mainstem Skagit/Tribs Winter	Mainstem Skagit/Tribs Winter
Finney Creek Summer	Finney Creek Summer
Sauk Summer	Sauk Summer
Sauk Winter	Sauk Winter
Cascade Summer	Cascade Summer
Cascade Winter	Cascade Winter
Stillaguamish Basin	
Stillaguamish Winter	Stillaguamish Winter
Deer Creek Summer	Deer Creek Summer
Not a historical population.	SF Stillaguamish Summer. Summer steelhead of Skamania-origin were introduced into the South Fork Stillaguamish River coincident with the construction of the Granite Falls fish ladder in the mid-1950s.
Canyon Creek Summer	Canyon Creek Summer
Snohomish Basin	
Snohomish/Skykomish Winter	Snohomish/Skykomish Winter
Pilchuck Winter	Pilchuck Winter
NF Skykomish Summer	NF Skykomish Summer
Not a historical population.	SF Skykomish Summer. Summer steelhead of Skamamia-origin were introduced into the South Fork Skykomish River coincident with the initiation of a trap-and-haul operation at Sunset Falls in the mid-1950s. Genetic analysis indicates significant differentiation from NF Skykomish Summer natural population and Reiter Pond Hatchery (Skamania-origin), but greater similarity to samples from the Reiter Pond Hatchery (Kassler and Hawkins, pers. comm.).
Tolt Summer	Tolt Summer
Snoqualmie Winter	Snoqualmie Winter

Table 5-1 (continued). Puget Sound region historical and extant natural steelhead populations.

Historical Population	Extant Population
Lake Washington Basin	
Lake Washington Winter	Lake Washington Winter
Duwamish/Green Basin	
Not a historical population.	Green Summer. Population originated from summer steelhead of Skamania-origin introduced in 1965.
Green Winter	Green Winter. Genetic analysis indicates significant differentiation from Puyallup Winter.
Puyallup Basin	
Mainstem Puyallup Winter	Mainstem Puyallup Winter
White (Puyallup) Winter	White (Puyallup) Winter
Carbon Winter	Carbon Winter
South Sound Basin	
Chambers Creek Winter	Extirpated.
Nisqually Winter	Nisqually Winter
Not a historical population.	Deschutes Winter. Winter steelhead of Chambers Creek-origin were introduced into the Deschutes River, but presence of naturally sustained population is unlikely.
Eld Inlet Winter	Eld Inlet Winter
Totten Inlet Winter	Totten Inlet Winter
Hammersley Inlet Winter	Hammersley Inlet Winter
Case/Carr Inlets Winter	Case/Carr Inlets Winter
East Kitsap Winter	East Kitsap Winter
Hood Canal	
Dewatto Winter	Dewatto Winter
Tahuya Winter	Tahuya Winter
Union Winter	Union Winter
Skokomish Summer	Skokomish Summer
Skokomish Winter	Skokomish Winter
Hamma Hamma Winter	Hamma Hamma Winter
Duckabush Summer	Duckabush Summer
Duckabush Winter	Duckabush Winter
Dosewallips Summer	Dosewallips Summer
Dosewallips Winter	Dosewallips Winter
Quilcene/Dabob Bays Winter	Quilcene/Dabob Bays Winter
Strait of Juan de Fuca	
Discovery Bay Winter	Discovery Bay Winter
Sequim Bay Winter	Sequim Bay Winter
Dungeness Summer	Dungeness Summer
Dungeness Winter	Dungeness Winter
Morse Cr/Independent Tribs. Winter	Morse Cr/Independent Tribs. Winter
Elwha Summer	Elwha Summer
Elwha Winter	Elwha Winter

Hatchery Broodstock

Hatchery programs in the Puget Sound region generally use broodstock of Chambers origin for winter steelhead programs and broodstock of Skamania origin for summer steelhead programs (Table 5-2). Two exceptions are conservation programs for winter steelhead operated on the Green River and on the Hamma Hamma River.

Table 5-2. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Puget Sound region. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Kendall Creek	Kendall(C) Winter	E	Chambers Winter	Tokul(C) Winter Skagit(C) Winter Bogachiel(C) Winter
Marblemount	Skagit(C) Winter	E	Chambers Winter	
Barnaby Slough	Skagit(C) Winter	E	Chambers Winter	
Whitehorse Ponds	Whitehorse(C) Winter	E	Chambers Winter	
Reiter Ponds	Reiter(S) Summer	E	Skamania Summer	
Tokul Creek	Tokul(C) Winter	E	Chambers Winter	Bogachiel(C) Winter
Palmer Ponds	Palmer(C) Winter	E	Chambers Winter	Tokul(C) Winter Bogachiel(C) Winter VanWinkle(C) Winter
Palmer Ponds	Palmer(S) Summer	E	Skamania Summer	Reiter(S) Summer
Soos [1]	Green Winter	N	Local	
Puyallup	Puyallup(C) Winter	E	Chambers Winter	Tokul(C) Winter Bogachiel(C) Winter
Hamma Hamma[2]	Hamma Hamma Winter	N	Local	
Dungeness	Dungeness(C) Winter	E	Chambers Winter	Bogachiel(C) Winter
Lower Elwha[3]	Elwha(C) Winter	E	Chambers Winter	Bogachiel(C) Winter

[1] Program operated by Muckleshoot Tribe.
[2] Cooperative program with Long Live the Kings.
[3] Program operated by Lower Elwha Klallam Tribe.

5.3.2 Olympic Peninsula

Natural Populations

The following description of the Olympic Peninsula ESU is primarily a summary of information from Busby et al. (1996). The Olympic Peninsula ESU includes the western Strait of Juan de Fuca and the Olympic Peninsula from west of the Elwha River, around Cape Flattery, and south to include all streams that drain into the Pacific Ocean North of Grays Harbor (Fig. 5-3). A rare, temperate rain forest ecosystem dominates the western slopes of the thrust-cored Olympic Mountains. Very high annual precipitation rates, restricted land use and access, along with favorable gradient and bedload combinations have produced the most robust wild steelhead stocks in the state. These physical and climatic differences were considered to contribute to the biological distinctiveness of steelhead in the ESU. Genetic analyses by WDFW indicates that populations in the western Strait of Juan de Fuca and the North Coast of Washington are similar to one another, yet distinct from those in other regions of western Washington. Also, the coast region north of Grays Harbor and the Chehalis basin contains fish and amphibians not found on the south coast (presumably reflecting the glacial history of the north coast). This observation provided the BRT with additional evidence that the western Olympic Peninsula should be considered ecologically distinct from other areas.

Genetic samples have been taken from steelhead collected at 15 locations within the geographic extent of the Olympic Peninsula ESU and allozyme analysis conducted for 56 polymorphic loci (Phelps et al. 1997). Many of the samples were from juveniles and in some cases may have included a mixture of summer steelhead, winter steelhead, and resident *O. mykiss*. As in the Puget Sound analysis, the consensus dendogram revealed little geographic structure among the sample groupings and bootstrap support for the groupings was generally poor.

In the absence of informative genetic analysis, we generally relied on the populations identified in WDF et al. (1993). Identification of these populations was based on the geographic isolation of spawning areas and spawn timing (WDF et al. 1993).

We identified 31 populations that historically were present within the Olympic Peninsula ESU (Table 5-3). No populations are known to have been extirpated and no new populations are known to have been established.

OLYMPIC PENINSULA STEELHEAD ESU

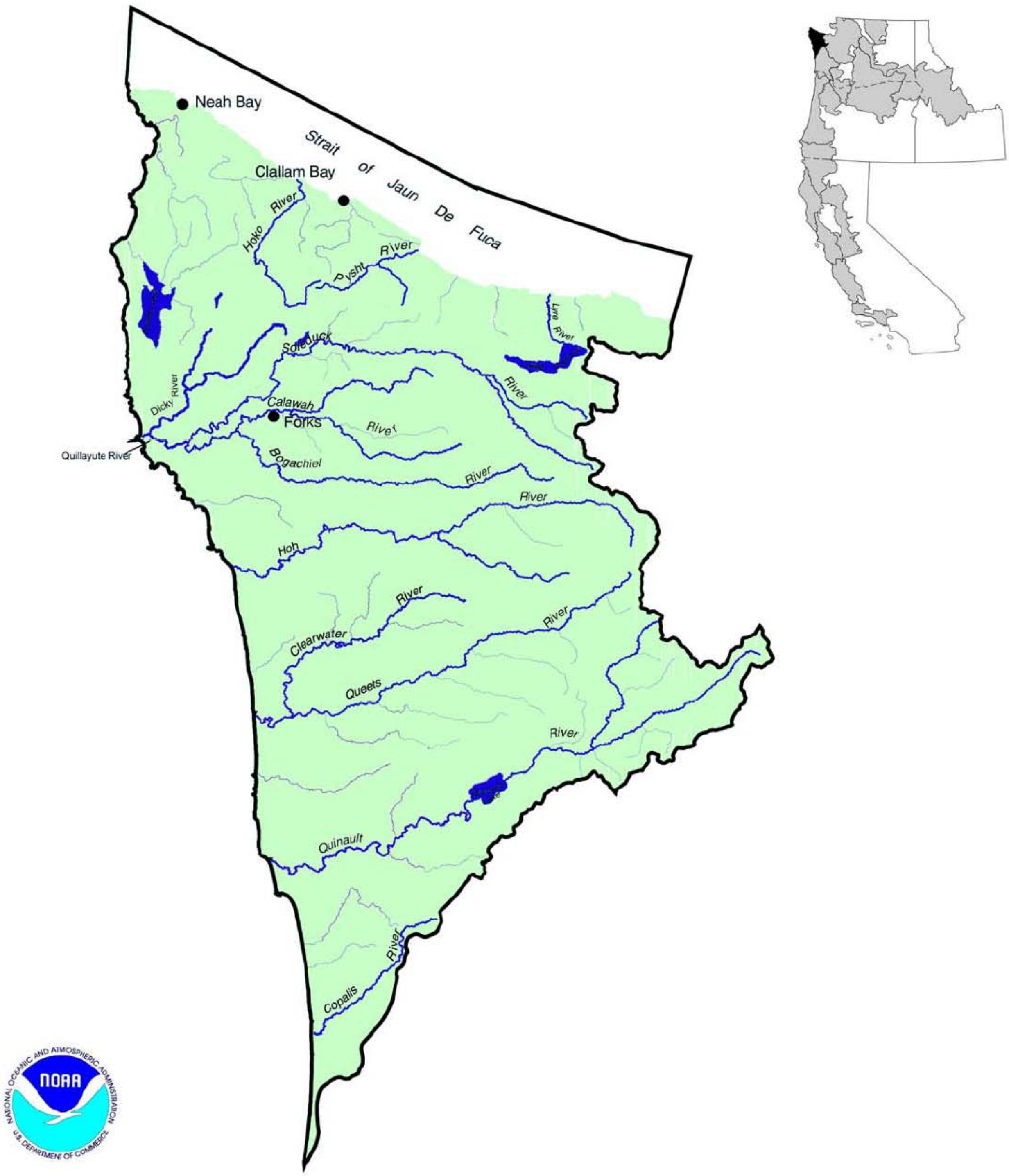


Figure 5-3. Olympic Peninsula ESU map.

Table 5-3. Olympic Peninsula region historical and extant natural steelhead populations.

Historical Population	Extant Population
Strait of Juan de Fuca	
Salt Creek/Independents Winter	Salt Creek/Independents Winter
Lyre Winter	Lyre Winter
Pysht/Independents Winter	Pysht/Independents Winter
Clallam Winter	Clallam Winter
Hoko Winter	Hoko Winter
Sekiu Winter	Sekiu Winter
Sail Winter	Sail Winter
Sooes/Ozette Basin	
Sooes/Waatch Winter	Sooes/Waatch Winter
Ozette Winter	Ozette Winter
Quillayute Basin	
Quillayute/Bogachiel Summer	Quillayute/Bogachiel Summer
Quillayute/Bogachiel Winter	Quillayute/Bogachiel Winter
Dickey Winter	Dickey Winter
Sol Duc Summer	Sol Duc Summer
Sol Duc Winter	Sol Duc Winter
Calawah Summer	Calawah Summer
Calawah Winter	Calawah Winter
Hoh Basin	
Goodman Creek Winter	Goodman Creek Winter
Mosquito Creek Winter	Mosquito Creek Winter
Hoh Summer	Hoh Summer
Hoh Winter	Hoh Winter
Kalaloch Basin	
Kalaloch Winter	Kalaloch Winter
Queets Basin	
Queets Summer	Queets Summer
Queets Winter	Queets Winter
Clearwater Summer	Clearwater Summer
Clearwater Winter	Clearwater Winter
Raft Basin	
Raft Winter	Raft Winter
Quinault Basin	
Lower Quinault/Quinault Lake Winter	Lower Quinault/Quinault Lake Winter
Quinault Summer	Quinault Summer
Upper Quinault Winter	Upper Quinault Winter
Moclips/Copalis Basins	
Moclips Winter	Moclips Winter
Copalis Winter	Copalis Winter

Hatchery Broodstock

Broodstock for hatchery programs in the Olympic Peninsula region originate from a variety of sources (Table 5-4). Broodstock of local origin is used at two hatcheries: 1) Snider Creek; and 2) Lake Quinault Hatchery. The Snider Creek program is conducted in cooperation with the Oympic Peninsula Guides Association with broodstock collected each year from the Sol Duc River. Broodstock for the Lake Quinault steelhead program are collected from Lake Quinault.

Table 5-4. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Olympic Peninsula region. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Hoko [1]	Hoko(C) Winter	E	Chambers Winter	Bogachiel(C) Winter
Makah NFH [2]	Sooes Winter	E	Quinault Winter	
Snider Creek	Sol Duc Winter	E	Local	
Bogachiel	Bogachiel(C) Winter	E	Chambers Winter	
Bogachiel	Bogachiel(S) Summer	E	Skamania Summer	
Quinault NFH [2]	Quinault Winter	E	Unknown	
Lake Quinault[3]	Lake Quinault Winter	N	Local	

[1] Program operated by the Makah Tribe.

[2] Program operated by the Fish and Wildlife Service.

[3] Program operated by the Quinault Indian Nation.

5.3.3 Southwest Washington

Natural Populations

The following description of the Southwest Washington ESU is primarily a summary of information from Busby et al. (1996). The range of this ESU includes all rivers draining into the major embayments of Grays Harbor, Willapa Bay, and the Columbia River up to (but not including) the Cowlitz River (Fig. 5-4). The geomorphology is characterized by the large estuarine environments developed by littoral sediment transport from the Columbia northward along the Pacific Coast. Some streams drain the temperate rain forest terrains of the Olympic Peninsula, but the apparently overriding feature is the large embayment environment common to all stocks in this ESU. Stream hydrology factors, such as gradient, presence of gravels, pools and riffles, and flow conditions are highly variable. The ESU is based on genetic data indicating that steelhead from the South Coast of Washington are distinct from those of the Olympic Peninsula. Relationships with other lower Columbia steelhead stocks were not clear at the time that the ESU was designated. Fish species in the Chehalis basin and the lowest portion of the Columbia River are similar, and sediments from the Columbia are known to be transported to Willapa Bay and Grays Harbor. This information provided the BRT with evidence of an ecological link between the South Coast of Washington and the lowest portion of the Columbia River basin.

We have further subdivided the Southwest Washington ESU into three components, Grays Harbor, Willapa, and Columbia Mouth, in recognition of the significant biological variation within the ESU and the size of the Chehalis Basin. The Chehalis River has the largest drainage area of any river in western Washington and includes the only summer steelhead populations in the ESU.

Genetic samples have been taken from steelhead collected at 15 locations within the geographic extent of the Southwest Washington ESU and allozyme analysis conducted for 56 polymorphic loci (Phelps et al. 1997). Many of the samples were from juveniles and in some cases may have included a mixture of summer steelhead, winter steelhead, and resident *O. mykiss*. A preliminary reanalysis using methods described in the Puget Sound section was conducted to evaluate the relationship between the samples. The consensus dendrogram revealed a geographic structure among the sample groupings with samples from each of the subregions (Grays Harbor, Willapa, Columbia Mouth) tending to form a group (Fig. 5-5).

SOUTHWEST WASHINGTON STEELHEAD ESU

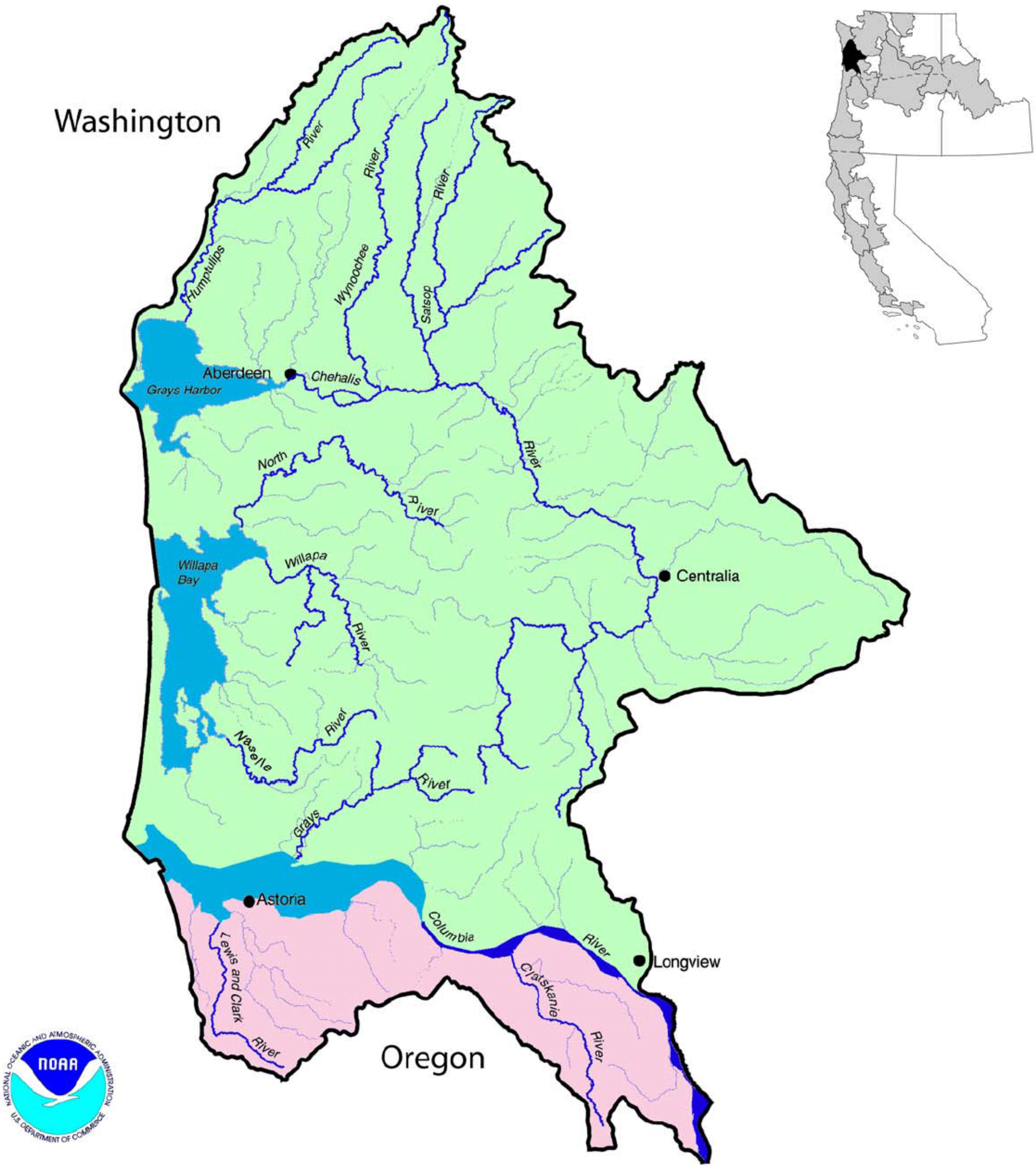


Figure 5-4. Southwest Washington ESU map.

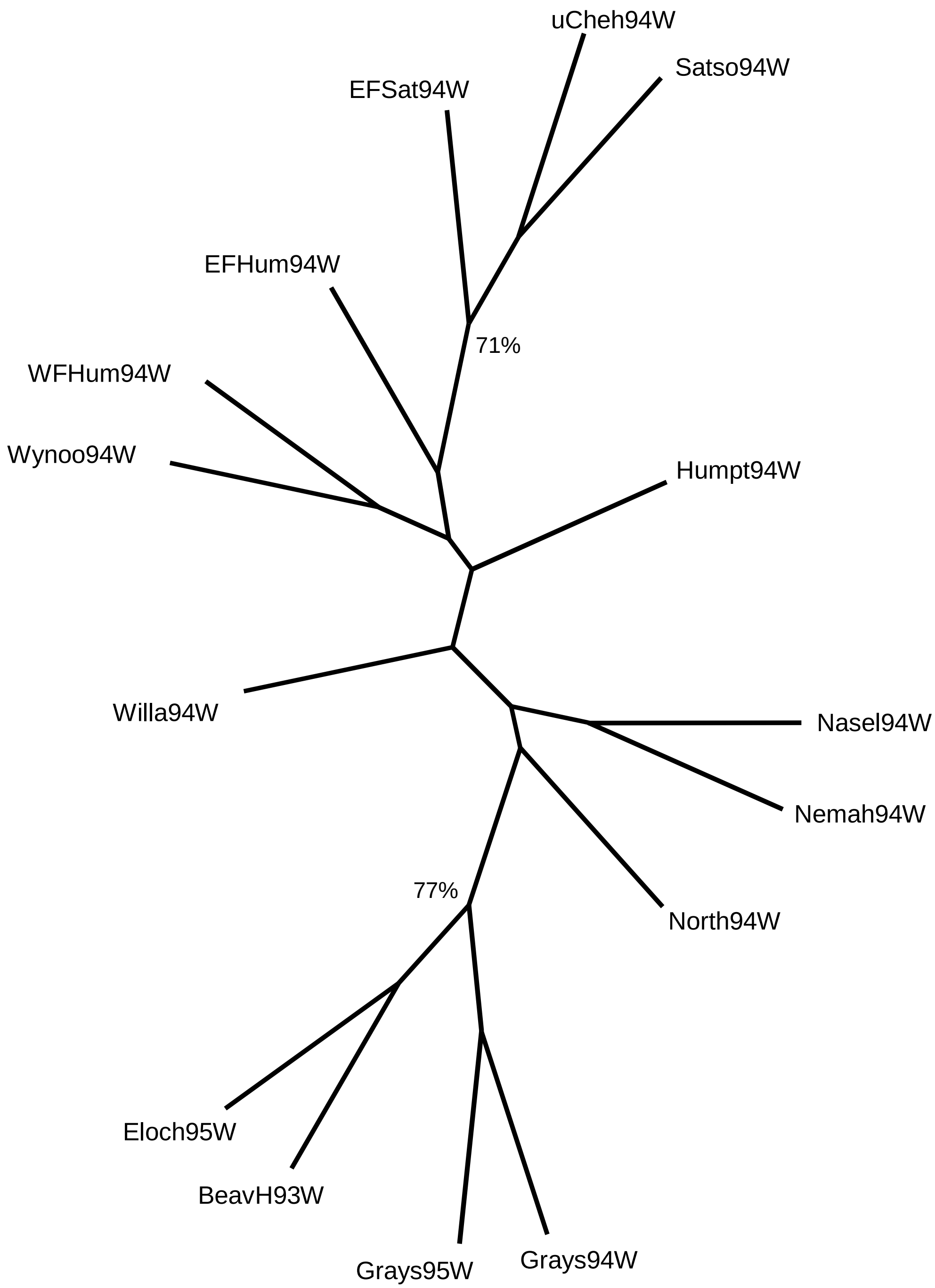


Figure 5-5. Consensus Neighbor-Joining tree for southwestern Washington coast steelhead collections using pairwise Cavalli-Sforza & Edwards chord distances (nodes with more than 60% bootstrap support labeled; using data for 56 allozyme loci).

In the absence of conclusive genetic analysis, we relied on the populations identified in WDF et al. (1993). Identification of these populations was based on the geographic isolation of spawning areas and spawn timing (WDF et al. 1993).

We identified 10 historical populations in Grays Harbor, 6 populations in Willapa Bay, and 3 populations in the Columbia Mouth subregion (Table 5-6). No populations are known to have been extirpated, and no new populations are known to have been established.

Table 5-6. Southwest Washington region historical and extant natural steelhead populations.

Historical Population	Extant Population
Grays Harbor	
Chehalis Summer	Chehalis Summer
Chehalis Winter	Chehalis Winter
Hoquiam Winter	Hoquiam Winter
Humptulips Summer	Humptulips Summer
Humptulips Winter	Humptulips Winter
Satsop Winter	Satsop Winter
Skookumchuck/Newaukum Winter	Skookumchuck/Newaukum Winter
South Bay Winter	South Bay Winter
Wishkah Winter	Wishkah Winter
Wynoochee Winter	Wynoochee Winter
Willapa Bay	
Bear River Winter	Bear River Winter
Naselle Winter	Naselle Winter
Nemah Winter	Nemah Winter
North/Smith Winter	North/Smith Winter
Palix Winter	Palix Winter
Willapa Winter	Willapa Winter
Columbia Mouth[1]	
Mill-Abernathy-Germany Winter	Mill-Abernathy-Germany Winter
Skamokawa-Elochoman Winter	Skamokawa-Elochoman Winter
Grays Winter	Grays Winter

[1] Steelhead stocks in the lower Columbia River basin from the mouth up to, but not including the Cowlitz River, are part of the Southwest Washington ESU; those from the Cowlitz through the Wind River are part of the Lower Columbia River ESU.

Hatchery Broodstock

Hatchery programs in the Grays Harbor region use a variety of local and nonlocal broodstock (Table 5-7). The Bingham Creek winter steelhead program was initiated with broodstock captured from the Satsop River. Current broodstock are a mixture of both natural-origin and adult returns from the initial releases from this program, with a minimum of 10% of the broodstock of natural-origin. The Eight Creek Acclimation Pond program is similar, except that the initial source of broodstock was natural-origin adults collected in the Chehalis River above the confluence of the Newaukum River.

All artificial production programs for winter steelhead in the Willapa and Columbia Mouth subregions use broodstock of Chambers origin (tables 5-8 and 5-9).

Table 5-7. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Grays Harbor region. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Humptulips	Humptulips(C) Winter	E	Chambers Winter	Bogachiel(C) Winter Quinault Winter
Lake Aberdeen	VanWinkle(C) Winter	E	Chambers Winter	Bogachiel(C) Winter Humptulips(C) Winter
Lake Aberdeen	Wynoochee Winter	N	Local	
Lake Aberdeen	VanWinkle(S) Summer	E	Skamania Summer	Skykomish(S) Summer
Bingham	Bingham Winter	N	Local	
Skookumchuck	Skookumchuck Winter	N	Local	
Eight [1]	Upper Chehalis Winter	N	Local	

[1] Cooperative program with the Upper Chehalis Fisheries Enhancement Group.

Table 5-8. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Willapa Bay subregion. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Forks Creek	Forks(C) Winter	E	Chambers Winter	Bogachiel(C) Winter
Naselle	Naselle(C) Winter	E	Chambers Winter	Bogachiel(C) Winter Willapa(C) Winter

Table 5-9. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Columbia River Mouth subregion. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Elochoman	Elochoman(C) Winter	E	Chambers Winter	Kalama(C) Winter Lewis(C) Winter
Beaver Creek [1]	Elochoman(C) Winter	E	Chambers Winter	Kalama(C) Winter Lewis(C) Winter

[1]Program identified for historical reference; facility closed in 1999.

5.3.4 Lower Columbia River

Natural Populations

The following description of the Lower Columbia River ESU is primarily a summary of information from Busby et al. (1996). The Lower Columbia ESU includes the Columbia River and its tributaries from the Cowlitz River up to and including the Wind River on the Washington side of the Columbia River, and from the lower Willamette River (below Willamette Falls) through the Hood River (inclusive) in Oregon (Fig. 5-6). The Washington portion is currently dominated by the major habitat disruption and recovery following the 1980 Mt. St. Helens eruption, and the influences of habitat alterations associated with urbanization and construction of Bonneville Dam. Genetic analyses available to the BRT indicated that lower Columbia steelhead were different from those in coastal streams of Oregon and Washington and from those in the upper Willamette River (above Willamette Falls). Steelhead from the Washougal, Wind and Big White Salmon rivers were genetically distinct from those originating from the south coast of Washington. Streams in this ESU drain the western Cascades from the southwestern flanks of Mt. Rainier to Mt. Hood.

The WLCTRT (Myers et al. 2004) identified 19 historical populations of steelhead in the Washington component of the Lower Columbia ESU (Table 5-9). Of these, 14 populations are believed to be currently extant. Four populations of winter steelhead on the Cowlitz River (Cispus, Tilton, Upper Cowlitz, Lower Cowlitz) are believed to have existed historically. However, construction of the Mayfield Dam in 1968 eliminated access to spawning habitat for these populations. Returning adults were taken to the Cowlitz Trout Hatchery to maintain the populations and initiate a late-winter steelhead artificial production program. The resultant late-winter population spawning in the lower Cowlitz River likely includes genetic representation from each of the four historical populations. The North Fork Lewis summer population was likely extirpated after construction of three dams on the North Fork Lewis River eliminated access to 80% of historical spawning and rearing habitat (Myers et al. 2004).

Introgression with hatchery fish of Chambers Creek type origin may have occurred in several of the populations. Although the genetic data are limited, a cluster analysis of samples of winter steelhead from the NF Toutle (Green) (labeled GrTou96W in Fig. 5-8) indicated similarity with samples from the Cowlitz early-winter hatchery program (a Chambers Winter type origin, labeled CowH96W in Fig. 5-8), Cedar Creek-North Fork Lewis (of Chambers Winter type origin, labeled CeLew96W in Fig. 5-8), and the Skamania hatchery winter program (of Chambers Winter type origin, labeled SkamH93W in Fig. 5-8). Potential effects of hatchery programs are discussed in greater detail in Chapter 7.

Figure 5-7. Lower Columbia River ESU map.

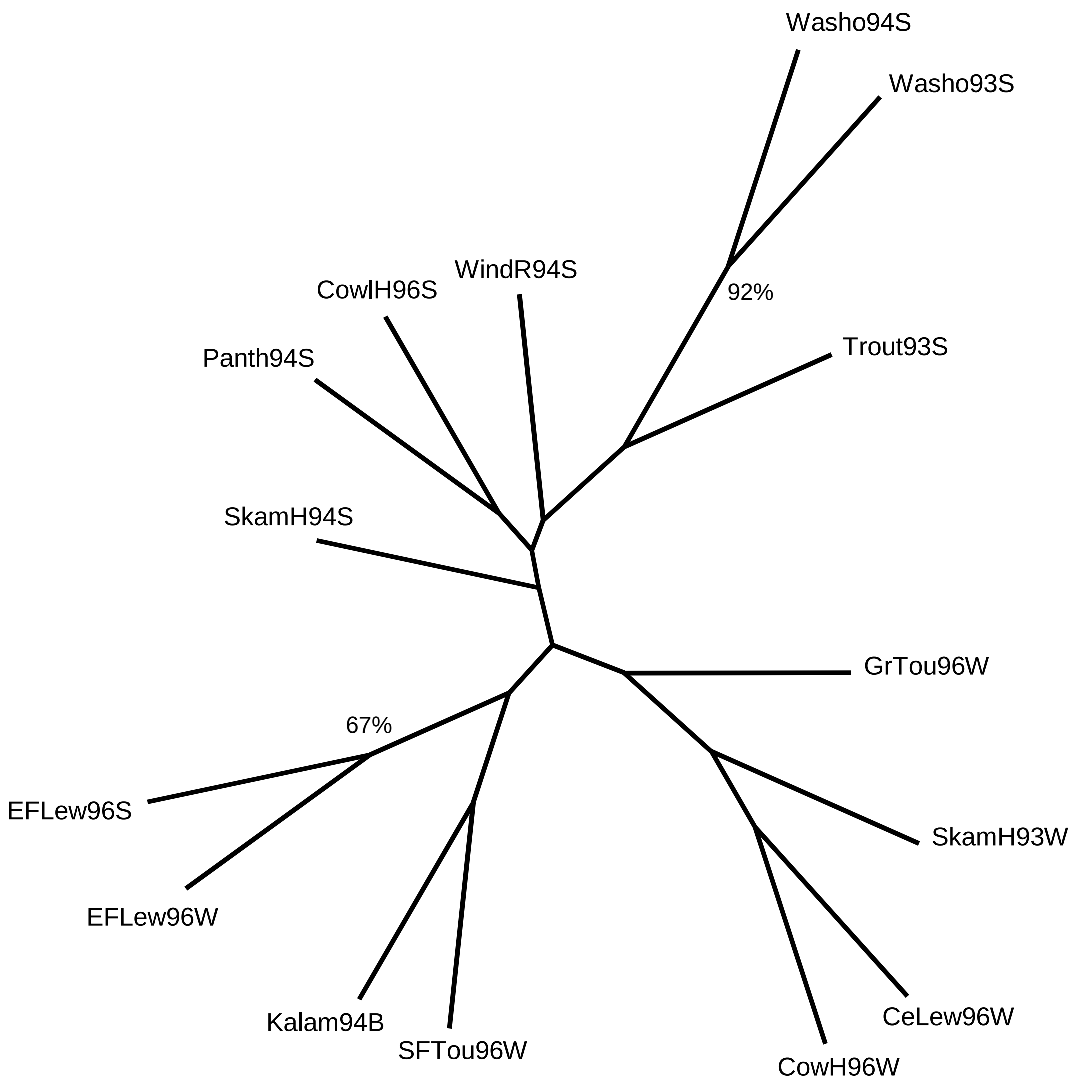


Figure 5-8. Consensus Neighbor-Joining tree for lower Columbia River steelhead collections using pairwise Cavalli-Sforza & Edwards chord distances (nodes with more than 60% bootstrap support labeled; using data for 56 allozyme loci).

Table 5-9. Lower Columbia River region historical and extant natural steelhead populations.

Historical Population	Extant Population
Cispus Winter Tilton Winter Upper Cowlitz Winter Lower Cowlitz Winter	Cowlitz River. Composite population resulted from collection of adults for broodstock after construction of Mayfield Dam.
NF Toutle (Green) Winter	Mainstem/NF Toutle Winter. NF Toutle (Green) population split into two components (Mainstem/NF Toutle Winter and Green Winter) based on analysis that indicates sufficient habitat is present within each component to support an independent population.
	Green Winter. Myers et al. (2004) state genetic analysis "suggest a strong similarity" between sample from Green and nonnative hatchery population. Subsequent WDFW analysis suggest more limited similarity between samples.
SF Toutle Winter	SF Toutle Winter. Genetic analysis indicates an association with other indigenous steelhead populations in this ESU, but significantly different than NF Toutle (Myers et al. 2004).
Coweeman Winter	Coweeman Winter. No genetic analysis available.
Kalama Winter	Kalama Winter. Genetic analysis of a mixed sample of summer and winter juveniles indicates that the population is distinct from hatchery populations (Myers et al. 2004).
Kalama Summer	Kalama Summer. Genetic analysis of a mixed sample of summer and winter juveniles indicates that the population is distinct from hatchery populations (Myers et al. 2004).
NF Lewis Winter	NF Lewis Winter. Myers et al. (2004) state genetic analysis "suggest a strong similarity" between sample from NF Lewis and nonnative hatchery population. Subsequent WDFW analysis suggest more limited similarity between samples.
EF Lewis Winter	EF Lewis Winter. Genetic analysis indicates a strong association with other indigenous steelhead populations in this ESU, but significantly different than NF Lewis Winter (Myers et al. 2004).
NF Lewis Summer	Potentially Extirpated. Construction of 3 dams on the North Fork Lewis River eliminated access to 80% of historical spawning and rearing habitat (Myers et al. 2004).
EF Lewis Summer	EF Lewis Summer. Genetic analysis indicates a strong association with other indigenous steelhead populations in this ESU (Myers et al. 2004).

Table 5-9 (continued). Lower Columbia River region historical and extant natural steelhead populations.

Historical Population	Extant Population
Salmon Creek Winter	Salmon Creek Winter. No genetic analysis available.
Washougal Winter	Washougal Winter. No genetic analysis available.
Washougal Summer	Washougal Summer. Genetic analysis indicates that greatest similarity is to Wind summer population.
Lower Gorge Winter	Lower Gorge Winter. No genetic analysis available.
Upper Gorge Winter	Wind Winter is component in Washington. No genetic analysis available.
Wind Summer	Wind Summer. Genetic analysis from three samples inconclusive.

Hatchery Broodstock

Hatchery programs in the Lower Columbia region typically use broodstock of Chambers Creek origin for winter steelhead programs and Skamania origin for summer steelhead programs (Table 5-10). Two exceptions are the Cowlitz Late Winter program and two programs on the Kalama that collect natural-origin broodstock. Broodstock collection for the Cowlitz Late Winter program was initiated after the construction of Mayfield Dam in 1968 and likely included representation from all four natural populations of winter steehead in the Cowlitz River. The Kalama Winter and Kalama Summer programs are maintained with steelhead collected from the Kalama River.

Table 5-10. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Lower Columbia River region. Parenthetic C included in broodstock name indicates Chambers origin; parenthetic S indicates Skamania origin. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Cowlitz Trout	Cowlitz(C) Winter	E	Chambers Winter	
Cowlitz Trout	Cowlitz Late Winter	N	Local	
Cowlitz Trout	Cowlitz(S) Summer	E	Skamania Summer	
Kalama Falls	Kalama(C) Winter	E	Chambers Winter	Elochoman(C) Winter Beaver(C) Winter
Kalama Falls	Kalama Winter	N	Local	
Kalama Falls	Kalama Summer	N	Local	
Kalama Falls	Kalama(S) Summer	E	Skamania Summer	
Merwin	Lewis(C) Winter	E	Chambers Winter	
Merwin	Lewis(S) Summer	E	Skamania Summer	
Skamania	Skamania(C) Winter	E	Chambers Winter	Elochoman(C) Winter Lewis(C) Winter Beaver(C) Winter Kalama(C) Winter
Skamania	Skamania(S) Summer	E	Skamania Summer	

5.3.5 Middle Columbia River

The following description of the Middle Columbia River ESU is primarily a summary of information from Busby et al. (1996). The Middle Columbia River ESU extends upstream from the Wind River through the Yakima River in Washington (excluding the Snake River System) and includes tributaries to the Columbia River originating in Oregon up through the Walla Walla River (Fig. 5-9). This intermontane area of Columbia plateau basalts is characterized by much drier weather and harsh seasonal temperature extremes, with little moderation from the shrub-dominated vegetation cover. Steelhead in the ESU are considered part of an inland genetic lineage. Genetic analyses available to the ICRT showed that steelhead from middle Columbia streams are distinct from Snake River populations. Analyses of naturally spawning steelhead from the upper Columbia were not available to the BRT for comparison with middle Columbia stocks; however Wells Hatchery steelhead (upper Columbia basin) were known to be distinct from middle Columbia steelhead. Inclusion of Klickitat and Yakima steelhead in this ESU was debated. The Klickitat has native summer and winter steelhead like the larger systems in the Lower Columbia ESU. No winter steelhead are seen upstream from the Klickitat. Klickitat steelhead were ultimately included in the Middle Columbia ESU based on their genetic similarity to other Middle Columbia stocks. Similarly, although Yakima steelhead were considered for inclusion in the Upper Columbia ESU, they were ultimately placed in the Middle Columbia ESU due to their genetic similarity to Klickitat steelhead and because of similarities to Middle Columbia life history and habitat features.

Nine historical populations have been identified in the Washington component of the Middle Columbia River ESU (Table 5-11)(ICTRT 2003; McClure and Cooney, pers. comm.). Eight of the nine populations are extant. The White Salmon Summer population was extirpated after construction in 1913 of the Condit Dam blocked access to spawning habitat.

Analysis of microsatellite genetic data suggests slight introgression of Skamania-type steelhead into the Naches and Upper Yakima populations (Busack et al. 2005). Samples of approximately 100 juvenile steelhead were collected at Roza Dam (sampled in 2000, 2001, and 2003), the Naches River (sampled in 2004), Toppenish Creek (sampled in 2000 and 2001), and Satus Creek (sampled in 2000 and 2001). Analysis using the STRUCTURE program (Pritchard et al. 2000) indicated that 6-9% of the multi-locus genotype of an average steelhead juvenile sampled in the Naches River or at Roza Dam was consistent with Skamania-type fish. The range was lower, 2-4%, for the samples from Toppenish Creek and Satus Creek. These slight relationships to Skamania-type fish could also be artifacts of shared polymorphisms or shared ancestry rather than introgression (Utter 1998; Busack et al. 2005).

MIDDLE COLUMBIA RIVER STEELHEAD ESU

Figure 5-7. Middle Columbia River ESU map.

Introgression with hatchery-origin rainbow trout may also have occurred in the Naches and Upper Yakima populations (Campton and Johnston 1985; Phelps et al. 2000). Phelps et al. (2000) concluded from an admixture analysis of parental source (Long 1991) that hatchery-origin rainbow trout were responsible for more than 10% of the gene pool for samples from Wilson Creek (Upper Yakima tributary) and the Roza trap. Potential effects of hatchery programs are discussed in greater detail in Chapter 7.

Table 5-11. Middle Columbia River region historical and extant natural steelhead populations.

Historical Population	Extant Population
White Salmon Summer	None. Condit Dam, constructed in 1913, blocked passage to spawning habitat.
Klickitat Summer-Winter	Klickitat Summer-Winter. Genetic analysis indicates differentiation from other populations (Phelps et al. 2000). Spawning area overlap and genetic samples from the sport fishery do not show strong segregation of summer and winter- run fish (ICTRT 2003).
Rock Creek Summer	Rock Creek Summer. No genetic analysis available.
Walla Walla Summer	Walla Walla Summer. Analysis indicates genetically distinct from Touchet Summer (ICTRT 2003) (Narum et al. In press).
Touchet Summer	Touchet Summer. Analysis indicates genetically distinct from Walla Walla Summer (ICTRT 2003) (Bumgarner et al. 2004).
Satus Creek Summer	Satus Creek Summer. Analysis indicates genetically distinct from other populations in the Yakima subbasin (McClure and Cooney, pers. comm.).
Toppenish Creek Summer	Toppenish Creek Summer. Analysis indicates genetically distinct from other populations in the Yakima subbasin (McClure and Cooney, pers. comm.).
Naches Summer	Naches Summer. Analysis indicates genetically distinct from other populations in the Yakima subbasin (ICTRT 2003). Some introgression with hatchery-origin rainbow trout and steelhead may have occurred (Phelps et al. 2000; Busack et al. 2005).
Upper Yakima Summer	Upper Yakima Summer. Analysis indicates genetically distinct from other populations in the Yakima subbasin (ICTRT 2003) with substantial gene flow between resident and anadromous *O. mykiss* (Pearsons et al. 1998). Some introgression with hatchery-origin rainbow trout and steelhead may have occurred (Phelps et al. 2000; Busack et al. 2005).

Hatchery Broodstock

The Touchet Summer endemic steelhead program was initiated in 2000 and uses broodstock collected from the Touchet River (Table 5-12). Program protocols require that no more than 35% of the broodstock is to be of hatchery-origin.

Table 5-12. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Middle Columbia River region. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Lyons Ferry	Touchet Summer	N	Local	
Lyons Ferry	Lyons Ferry	E	Wells Wallowa[1]	

[1] The Wallowa program was initiated with adults collected at Ice Harbor Dam in 1976, adults collected at Little Goose Dam in 1977-1978, and embryos from Pahsimeroi Hatchery in 1979 (Whitesel et al. 1998).

5.3.6 Upper Columbia River

The following description of the Upper Columbia River ESU is primarily a summary of information from Busby et al. (1996). The Upper Columbia River ESU encompasses the Columbia River System upstream of the Yakima River to the U.S.-Canada border. Passage up the Columbia River itself is blocked at Chief Joseph Dam (Fig. 5-8). The rivers in this ESU drain the Northern Cascades and the Okanogan Highlands physiographic provinces, which feature a complex geology that includes glacial, volcanic and marine terrains. These have been deeply incised to produce generally low gradient streams beyond the headwaters. Extremes in temperature, precipitation and snowpack accumulation produce erratic cold water temperatures and stream flows which tend to extend growth and maturation periods beyond those typical of the coastal rivers of the Pacific Northwest. Life histories of Upper Columbia steelhead are similar to those of other inland populations in that after returning from saltwater, most hold in freshwater for nearly a year before spawning. Although most steelhead smolt at age two (Wenatchee 66%; Methow and Okanogan 78%) in the Upper Columbia region (Murdoch, pers. comm.), smolting can take place as late as age seven (Mullan et al. 1992). This prolonged juvenile freshwater residence is probably the result of very cold stream temperatures. Due to a lack of trapping facilities, little is known about steelhead destined for the Entiat River.

Eleven populations are believed to have existed in this ESU historically (Table 5-13)(ICTRT 2003; McClure and Cooney, pers. comm.). Six of the populations (Sanpoil, Kettle/Colville, Pend Oreille, Kootenay, Spokane, and Hangman) were extirpated after construction of the Grand Coulee Dam in 1939 blocked access to more than 50% of the river miles previously accessible to steelhead originating from this ESU (NRC 1996). The status of the Okanogan and Crab Creek populations is uncertain. Analysis suggests that sufficient habitat was present historically to support independent populations and limited surveys have revealed small numbers of natural-origin fish using Omak Creek in recent years (ICTRT 2003; Arterburn, pers. comm.).

Genetic analysis on three of the extant populations (Wenatchee, Entiat, and Methow) has been difficult for three reasons: 1) the Grand Coulee Fish Maintenance Project (Fish and Hanavan 1948) probably resulted in the mixing of steelhead from all areas upstream of Rock Island Dam; 2) artificial production programs released juvenile steelhead that originated from broodstock of unknown origin collected at Wells Dam or Priest Rapids Dam; and 3) genetic samples were often small and collected from juvenile fish (Chapman et al. 1994; Ford et al. 2001). However, three general conclusions were: 1) introgression of steelhead of Skamania-origin has not occurred (Chapman et al.

UPPER COLUMBIA RIVER STEELHEAD ESU

Figure 5-12. Upper Columbia River ESU map.

1994); 2) there are significant differences in allele frequencies among the samples (Chapman et al. 1994; Ford et al. 2001); and 3) there is little or no geographic structure to observed differences in allele frequencies (Chapman et al. 1994; Ford et al. 2001).

Table 5-13. Upper Columbia River region historical and extant natural steelhead populations.

Historical Population	Extant Population
Crab Creek	Uncertain. Population identification based on size of drainage area, spawning distribution, and presence of resident *O. mykiss* that showed high genetic differentiation from hatchery stocks (Bettles 2004). Resident component likely more dominant and critical to the long-term persistence of the population (ICTRT 2003).
Wenatchee	Wenatchee. Population identification based on genetic data, size of drainage area, and spawning distribution (ICTRT 2003).
Entiat	Entiat. Population identification based on genetic data, size of drainage area, and spawning distribution (ICTRT 2003).
Methow	Methow. Population identification based on genetic data, size of drainage area, and spawning distribution (ICTRT 2003).
Okanogan	Uncertain. As limited number of natural-origin returns with a large proportion of hatchery-origin spawners (ICTRT 2003).
Sanpoil	Extirpated.
Kettle/Colville	Extirpated.
Pend Oreille	Extirpated.
Kootenay	Extirpated.
Spokane	Extirpated.
Hangman Creek	Extirpated.

Hatchery Broodstock

Broodstock collection for hatchery programs throughout the Upper Columbia region occur at the Eastbank and Wells hatcheries (Table 5-14).

The Eastbank steelhead program was modified in 1998 to collect hatchery and natural-origin adults (goal is 50% natural-origin) at Dryden and Tumwater dams on the Wenatchee River. For brood years 1997 through 2002, an average of over 50% of the broodstock collected was of natural-origin (Murdoch et al. 1998; 2000a; 2000b; 2001; Tonseth et al. 2004).

The Wells Hatchery steelhead program was initiated in the late-1960s with broodstock captured at Priest Rapids Dam. Broodstock in more recent years have been collected at Wells Dam and at the Wells Hatchery, with contributions from both hatchery and natural-origin adults (Chapman et al. 1994; Snow 2004). The Wells steelhead program broodstock collection goal was modified in 2003 to include 33% natural-origin adults.

In 2003, the Colville Tribes initiated a local broodstock collection program, collecting steelhead returning to Omak Creek (Arterburn, pers. comm.). Eggs are incubated and juvenile steelhead are reared at the Colville Trout Hatchery. This is a conservation program with the goal of releasing 20,000 smolts in the Okanogan subbsasin.

Table 5-14. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Upper Columbia region. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Eastbank	Eastbank	E	Wenatchee[1]	Wells Priest Rapids Dam [2]
Wells	Wells	E	Priest Rapids Dam	
Cassimer Bar	Okanogan	N	Local [3]	

[1] Broodstock collected at Dryden and Tumwater dams.

[2] Hatchery and natural-origin broodstock collected at Priest Rapids Dam for the 1997 brood year.

[3] Program operated by the Confederated Tribes of the Colville Reservation; broodstock collected in Omak Creek.

5.3.7 Snake River Basin

The following description of the Snake River ESU is primarily a summary of information from Busby et al. (1996). The Snake River ESU extends from the Snake River mouth in SE Washington into NE Oregon and much of Idaho (Fig. 5-13). Streams originate in the area of mature, eroded landscape dominated by the exposed granitic terrains of the large Idaho Batholith. This results in rivers draining extensive, open, low relief areas in a warmer and more alkaline setting than the other geographic regions. Subbasins in the Washington component of the ESU differs in that the streams arise from the relatively low elevation, basalt dominated Blue Mountains. This ESU also has migration distances and spawning elevations that are generally greater than the other populations in the state. Most of these populations are thought to be fairly well isolated from populations outside the Snake basin. Genetic and meristic data available to the BRT both indicated that Snake basin steelhead are distinct from those outside the basin.

The ICTRT identified 40 populations of steelhead that historically existed in the Snake River Basin ESU (McClure and Cooney, pers. comm.). Only four of those populations have spawning areas located at least partially in Washington (Table 5-15): 1) Tucannon; 2) Asotin Creek; 3) Lower Grande Ronde; and 4) Joseph Creek. Additional small aggregations of spawning steelhead utilize small streams that enter the Snake between the Tucannon River and the Oregon state boundary. These groups do not meet the criteria for a population as defined by the ICTRT, and therefore were grouped based on proximity to identified populations (e.g., Alpowa and Almota were grouped with Asotin; Couse and Tenmile were grouped with Asotin).

Table 5-15. Snake River Basin region historical and extant natural steelhead populations.

Historical Population	Extant Population
Tucannon	Tucannon. Genetic analyses indicate similarity with Asotin; populations identified as independent based on distance between spawning areas (ICTRT 2003).
Asotin Creek	Asotin Creek. See Tucannon comments.
Lower Grande Ronde	Lower Grande Ronde. Genetic samples from this area formed a distinct cluster and spawning areas were well-separated from other potential populations (ICTRT 2003).
Joseph Creek	Joseph Creek. Genetic samples from this area formed a distinct cluster and spawning areas were well-separated from other potential populations (ICTRT 2003).

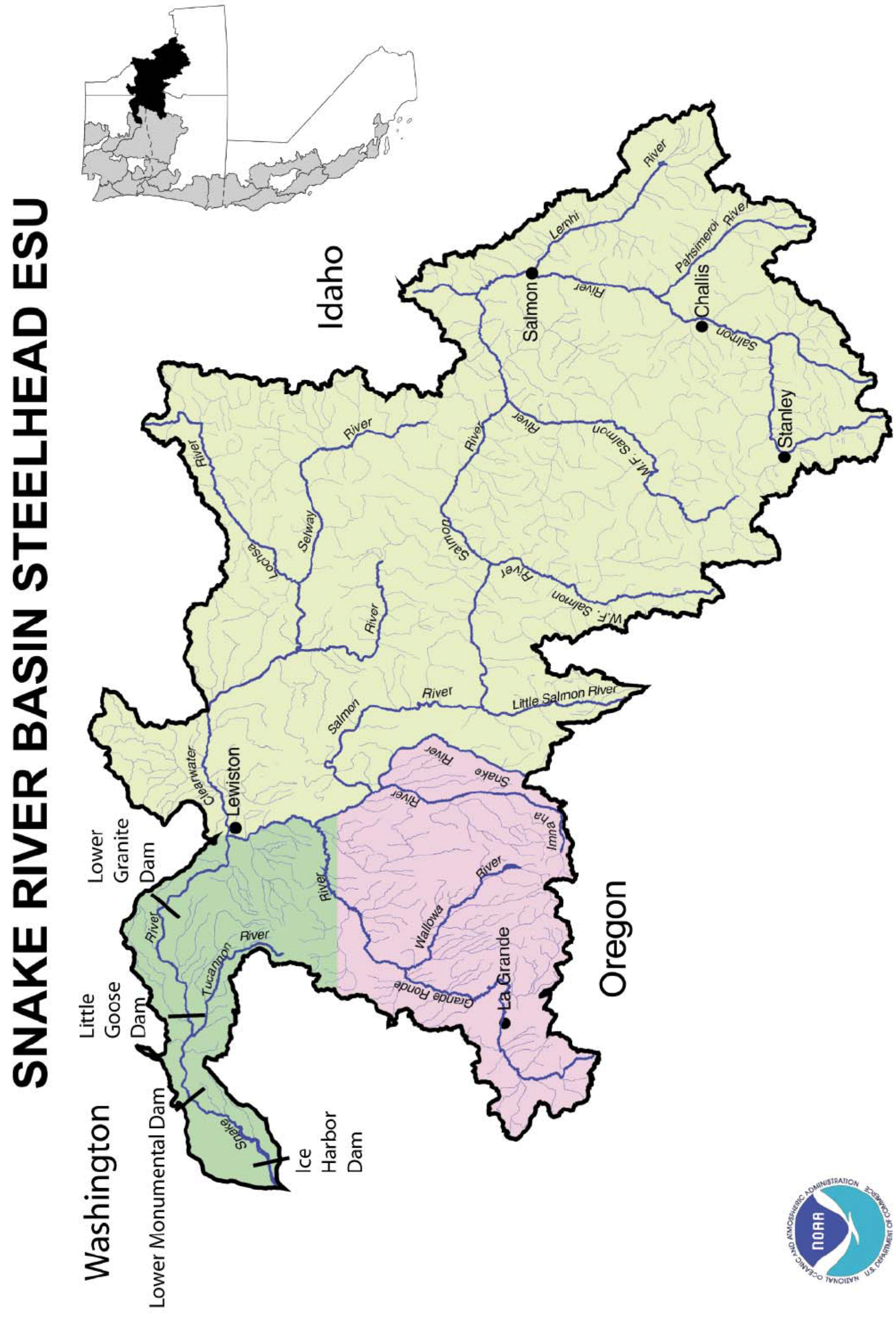


Figure 5-13. Snake River Basin ESU map.

Hatchery Broodstock
The Wallowa stock is the orginal source of broodstock for several WDFW and ODFW hatchery programs (Table 5-16). It was originally derived steelhead trapped at Ice Harbor and Little Goose dams (Whitesel et al. 1998). The stock is therefore likely made up of both “A” and “B” run steelhead from the Snake River basin, and could include fish from Asotin, Clearwater, Salmon and Grande Ronde basins.

The Cottonwood Acclimation Pond program was initiated in 1984 with the Wallowa stock. A permanent adult trapping site was installed in Cottonwood Creek to trap hatchery broodstock beginning in 1992. Prior to that and for a few years following, WDFW received eggs from ODFW in order to reach program goals.

The Lyons Ferry steelhead program was initiated in 1982 using Wallowa and Wells broodstock. In subsequent years, returning adult steelhead were trapped at the Lyons Ferry Hatchery. Because of the location of the broodstock collection site relative to other hatchery programs in the Snake Basin, Lyons Ferry broodstock is likely to have included adults of Skamania (likely very small contribution), Pahsimeroi (contributed in two years), Oxbow (contributed in two years), and Clearwater origin (likely small contribution)(Schuck 1998; Schuck pers. comm.).

The Tucannon endemic broodstock program was initiated in 2000 in response to concerns that had been raised about the non-local nature of the steelhead broodstock used at the Lyons Ferry Hatchery. Natural-origin broodstock are captured at the Lower Tucannon Trap located at rkm 17.7 (Bumgarner et al. 2004).

Table 5-16. Hatchery broodstock, broodstock origin, and other sources of eggs, juveniles, or adults in the last 10 years for hatchery programs located in the Snake Basin region. Spawn timing is identified relative to local natural population as early (E) or normal (N).

Facility	Broodstock	Spawn Timing	Broodstock Origin	Other Sources
Cottonwood	Cottonwood	N	Wallowa[1]	
Lyons Ferry	Lyons Ferry	E	Wells Wallowa[1]	
Lyons Ferry	Tucannon	N	Local	

[1] The Wallowa program was initiated with adults collected at Ice Harbor Dam in 1976, adults collected at Little Goose Dam in 1977-1978, and embryos from Pahsimeroi Hatchery in 1979 (Whitesel et al. 1998).

5.4 Discussion

Limitations of Population Analysis

Accurate identification of steelhead populations requires collecting and carefully analyzing biological data on spawning locations, spawn timing, and genetic characteristics of spawning aggregations. In our review of the data available for steelhead in Washington, we found numerous cases where basic biological data are currently not available. Exact spawning locations are not known for 17 (or 12%) of currently identified populations. Good data for spawn timing are not available for 29 (or 21%) of the populations. Improved confidence in our definition of populations will require the identification, prioritization, and collection of additional data on spawning location, spawn timing, and genetic characteristics.

Genetic analysis is potentially a powerful tool for identifying population and metapopulation structure. However, results from allozyme analysis of samples from juveniles in Puget Sound, the Olympic Peninsula, and Southwest Washington were often inconclusive. The lack of geographic structure and the inconsistent grouping of samples could result from several factors. These include: 1) insufficient genetic variability in the 56 loci used for the analysis; 2) samples that include a mixture of run timing (summer and winter), life history types (resident and anadromous), or populations; 3) insufficient sample sizes; 4); variable but significant levels of genetic introgression from one or both hatchery strains of steelhead (Chambers Creek hatchery winter-run and Skamania Hatchery summer-run) historically released into many of these rivers; or 5) a population structure characterized by substantive gene flow across broad geographic areas. Although the latter explanation cannot be completely dismissed, population structure has been identified at a relatively fine scale in western Washington when steelhead samples are carefully selected and analyzed (Marshall et al. 2004; Kassler and Hawkins, pers. comm.).

Population structure should be frequently reviewed to maximize the value of new data collection efforts and rapidly improving techniques for genetic analysis. Careful review and analysis of genetic and other biological data by the WLCTRT and ICTRT has resulted in substantial improvement in our understanding of the population structure of steelhead in the Columbia Basin. A systematic review of the structure of populations in the Puget Sound, Olympic Peninsula, and Southwest Washington ESUs has not been conducted since 1992. Building on the tools developed by the WLCTRT and ICTRT, a consistent procedure for evaluating population structure should be defined and applied in these ESUs.

Population Structure

The hierarchy in the genetic organization of steelhead is based on locally adapted populations. Maintenance of this hierarchy assures not only the short-term production of steelhead from natural habitat, but also the continuing evolution and preservation of the species. Our analysis indicates that substantial loss of historical populations has occurred in some ESUs in Washington (Table 5-17). The percent of historical populations remaining in each ESU ranges from 100% in the Olympic Peninsula and Southwest Washington ESUs to only 45% in the Upper Columbia ESU. The loss of historical anadromous populations has generally resulted from the construction of dams that block access to spawning areas. However, continued human population growth and development in Washington have the potential to place additional populations at risk through a variety of mechanisms (Lackey 2003).

Table 5-17. Summary of historical population, number of historical populations remaining, and percent of historical populations remaining.

ESU	Number of Historical Populations	Number of Historical Populations Remaining	% of Historical Populations Remaining
Puget Sound	51	49	96%
Olympic Peninsula	31	31	100%
Southwest Washington	19	19	100%
Lower Columbia River [1]			
Within Washington	19	14 [2]	74%
Total ESU	28	23	82%
Middle Columbia River [3]			
Within Washington	9	8	89%
Total ESU	20	18	90%
Upper Columbia River [3]	11	5	45%
Snake River Basin [3]			
Within Washington	4	4	100%
Total ESU	40	25	62%
All			
Within Washington	144	130	90%
Total ESU	200	170	85%

[1] Source is Myers et al. (2004)
[2] Based on loss of 4 winter populations in the Cowlitz River. A late-run winter steelhead population on the Cowlitz River may retain some characteristics of all historical populations.
[3] Source is McClure and Cooney (pers. comm.).

Riddell (1993) anticipated many of the current questions posed in recovery planning by suggesting that resource managers would more frequently be asked “what to conserve” and policy makers would have to consider “at what cost”. Riddell noted that the simplest answer to the first question was “Everything” but, pragmatically, a broad range of potentially conflicting societal objectives are likely to make that infeasible (Lackey 2003). Science can help answer the first question by evaluating the biological consequences of the loss of a population, and a number of approaches have been proposed (Riddell 1993; Allendorff et al. 1997; McElhany et al. 2000). Many similarities exist among the approaches and we have restated the central themes below:

1) Has the population been unaffected by the introduction of exogenous species and/or has the habitat occupied not been disrupted by anthropogenic activities (Riddell 1993; Allendorff et al 1997)?
2) Does the population exhibit unique genetic traits (Riddell 1993, Allendorff et al. 1997)?
3) Does the population occupy atypical habitat or express unusual phenotypic traits (Riddell 1993; Allendorff et al. 1997)?
4) Is the population a member of a native assemblage of species that is unusual or rare for steelhead (Allendorff et al. 1997)?
5) Does the population or group of populations provide a dispersed spatial distribution within an ESU (McElhany et al. 2000)?
6) Is the population necessary to provide connectivity among the components of a metapopulation (McElhany et al. 2000)?

New Populations

In a small number of cases, steelhead populations have been introduced into watersheds where they were not present historically. Generally, hatchery populations have been introduced by WDFW to take advantage of newly accessible habitat where upstream passage at waterfalls was provided or to provide a new opportunity for harvest. Despite this spatial separation, these introduced populations may have ecological or genetic interactions with an indigenous population. Past and future introductions should be carefully evaluated relative to genetic and ecological interactions with existing populations of steelhead and the native assemblage of species.

5.5 Findings and Recommendations

Finding 5-1. Short-term abundance and long-term persistence of the steelhead resource requires viable, locally-adapted, diverse populations, but a substantial loss of population structure has occurred in some, but not all regions. The percentage of historical populations remaining in 7 Washington regions ranges from 45%-100%. The two regions with 100% of the historical populations remaining - Olympia Peninsula and Southwest Washington - are both located on the Washington coast. The Upper Columbia River region has the smallest percentage of the historical populations remaining (45%).

Recommendation 5-1. Pursue opportunities to preserve and restore population structure, spatial structure, and within-population diversity through careful review of harvest, hatchery, and habitat management and implementation of improved strategies.

Finding 5-2. The population structure of steelhead in the Puget Sound, Olympic Peninsula, and Southwest Washington regions is uncertain. Inadequate genetic samples are currently available and new tools developed and applied by technical recovery teams have not been systematically applied in these regions.

Recommendation 5-2. Evaluate the population structure of steelhead in the Puget Sound, Olympic Peninsula, and Southwest Washington regions. Evaluate assumptions of the 1992 comanager analysis and, building on the tools developed by the Puget Sound, Willamette/Lower Columbia, and Interior Columbia technical recovery teams, define and implement a consistent procedure for evaluating population structure.

Finding 5-3. Steelhead life history diversity creates significant challenges for adequate sampling and accurate genetic analysis. Genetic analysis is potentially a powerful tool for identifying population and metapopulation structure. However, genetic analyses of previous samples from juveniles of potentially mixed life history types were often inconclusive. Newer genetic markers, such as single nucleotide polymorphisms (SNPs) and microsatellites, may enhance the power of genetic analyses, but the development and implementation of improved sampling protocols will be required.

Recommendation 5-3. Focus future collection of genetic samples in areas with significant uncertainty in population structure. Collect genetic samples for microsatellite or SNP analysis with methods that assure run timing and life history type are known. Conduct analyses using high-resolution DNA markers appropriate to research objectives.

5.6 References Cited

Allendorf, F.W., D. Bayles, D. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nelson, P. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11(1): 140-152.

Bettles, C. M. 2004. Preliminary assessment of genetic population structure of *Oncorhynchus mykiss* within the Crab Creek Subbasin, Washington State. Washington Department of Fish and Wildlife, Genetics Laboratory Report. Olympia, Washington

Bumgarner, J., J. Dedloff, M. Herr, M.P. Small. 2004. Lyons Ferry Complex hatchery evaluation: Summer steelhead annual report 2003 run year. Annual Report FPA 04-15. Washington Department of Fish and Wildlife, Olympia, Washington.

Busack, C., A. Frye, T. Kassler, T. Pearsons, S.L. Schroder, J. Von Bargen, S. Young, C. M. Knudsen, and G. Hart. 2005. Yakima/Klickitat Fisheries Project Genetic Studies; Yakima/Klickitat Fisheries Project Monitoring and Evaluation Report, Project No. 199506424.

Busby, P. J., T.C. Wainwright, G.J. Bryant, L. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-27.

Campton, D.E., and J.M. Johnston. 1985. Electrophoretic evidence for a genetic admixture of native and non-native rainbow trout in the Yakima River, Washington. Transaction American Fisheries Society 114: 782-793.

Cavalli-Sforza, L.L. and A.W.F. Edwards. 1967. Phylogenetic analysis, models and estimation procedures. Evolution 21: 550-570.

Chapman, D., C. Peven, T. Hillman, A. Giorgi, and F. Utter. 1994. Status of summer steelhead in the mid-Columbia Region. Don Chapman Consultants, Boise, Idaho.

Crawford, B. A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Washington Department of Game, Olympia, Washington.

Felsenstein, J. 1989. PHYLIP - Phylogeny Inference Package (version 3.2). Cladistics 5: 164-166.

Fish, F.F., and M.G. Hanavan. 1948. A report on the Grand Coulee Fish Maintenance Project 1938-1947. U.S. Fish and Wildlife Service, Special Science Report 55.

Ford, M., P. Budy, C. Busack, D. Chapman, T. Cooney, T. fisher, J. Geiselman, T. Hillman, J. Lukas, C. Peven, C. Toole, E. Weber, and P. Wilson. 2001. Upper Columbia River steelhead and spring chinook salmon population structure and biological requirements. Unpublished report available from National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Glaubitz, J.C. 2003. CONVERT (version 1.2): A user-friendly program to reformat diploid genotypic data for commonly used population genetic software packages. http://www.agriculture.purdue.edu/fnr/html/faculty/Rhodes/Students%20and%20Staff/glaubitz/software.htm

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-66.

Hatchery Scientific Review Group (HSRG). 2002. Hatchery reform recommendations for the Puget Sound and coastal Washington Hatchery Reform Project. Long Live the Kings, Seattle, Washington. Report available at http://www.hatcheryreform.org.

Hatchery Scientific Review Group (HSRG). 2003. Hatchery reform recommendations for the Puget Sound and coastal Washington Hatchery Reform Project. Long Live the Kings, Seattle, Washington. Report available at http://www.hatcheryreform.org.

Hatchery Scientific Review Group (HSRG). 2004. Hatchery reform recommendations for the Puget Sound and coastal Washington Hatchery Reform Project. Long Live the Kings, Seattle, Washington. Report available at http://www.hatcheryreform.org.

Hilborn, R. 1985. Apparent stock recruitment relationships in mixed stock fisheries. Canadian Journal of Fisheries and Aquatic Sciences 42: 718-723.

Interior Columbia Technical Recovery Team (ICTRT). 2003. Independent populations of Chinook, steelhead, and sockeye for listed evolutionarily significant units within the Interior Columbia River Domain. IC-TRT Report. NOAA Fisheries, Northwest Fisheries Science Center, Seattle, Washington. Report available at http://www.nwfsc.noaa.gov/trt/trt_columbia.htm.

Lackey, R.T. 2003. Pacific Northwest salmon: forecasting their status in 2100. Reviews in Fisheries Science 11(1): 35-88.

Larson, R. W., and J. H. Ward. 1955. Management of steelhead trout in the state of Washington. Transactions of the American Fisheries Society 84: 261-274.

Long, J.C. 1991. The genetic structure of admixed populations. Genetics 127: 417-428.

Marshall, A.R., M. Small, and S. Foley. 2004. Genetic relationships among anadromous and non-anadromous *Oncorhynchus mykiss* in Cedar River and Lake Washington – implications for steelhead recovery planning. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-42.

Myers, J., C. Busack, D. Rawding, and A. Marshall. 2004. Historical population structure of Willamette and Lower Columbia River basin Pacific salmonids. WLC-TRT Report. NOAA Fisheries, Northwest Fisheries Science Center, Seattle, Washington. Report available at http://www.nwfsc.noaa.gov/trt/trt_wlc.htm.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillmann, and J.D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. Monograph I, U.S. Fish and Wildlife Service, Leavenworth, Washington.

Murdoch, A., K. Petersen, T. Miller, and M. Tonseth. 1998. Annual progress report for Wenatchee summer steelhead, 1997 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Murdoch, A., K. Petersen, T. Miller, and M. Tonseth. 2000a. Annual progress report for Wenatchee summer steelhead, 1998 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Murdoch, A., K. Petersen, T. Miller, and M. Tonseth. 2000b. Annual progress report for Wenatchee summer steelhead, 1999 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Murdoch, A., T. Miller, K. Petersen, and C. Kamphaus. 2001. Annual progress report for Wenatchee summer steelhead, 2000 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Narum, S.R., C. Contour, A. Talbot, and M.S. Powell. In press. Genetic divergence of sympatric resident and anadromous forms of *Oncorhynchus mykiss* in the Walla Walla River, USA. Journal of Fish Biology.

National Research Council (NRC). 1996. Upstream: salmon and society in the Pacific Northwest. Report of the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids for the National Research Council of the National Academy of Sciences. Washington, D.C., National Academy Press.

National Marine Fisheries Service (NMFS). 2003. Hatchery Broodstock Summaries and Assessments for Chum, Coho, and Chinook Salmon and Steelhead Stocks within Evolutionarily Significant Units Listed Under the Endangered Species Act. Unpublished report available of the National Marine Fisheries Service available at http://www.nwr.noaa.gov/AlseaResponse/20040528/FinalSSHAG_Report0403I.pdf.

National Marine Fisheries Service NMFS. 2004. Salmonid hatchery inventory and effects evaluation report. Unpublished report available of the National Marine Fisheries Service available at http://www.nwr.noaa.gov/1srd/Prop_Determins/Inv_Effects_Rpt/

Page, R.D.M. 1996. TREEVIEW: An application to display phylogenetic trees on personal computers. Computer Applications in the Biosciences 12: 357-358.

Pautzke, C. F., and R. C. Meigs. 1940. Studies on the life history of the Puget Sound steelhead trout. Transactions of the American Fisheries Society 70: 209-220.

Pearsons, T.N., G.A. McMichael, K.D. Ham, E.L. Bartrand, A.L. Fritts, C.W. Hopley. 1998. Washington Department of Fish and Wildlife, Yakima River Species Interactions Studies, Progress Report 1995-1997. Report to Bonneville Power Administration, Contract No. 1996BI64878, Project No. 199506402. (BPA Report DOE/BP-64878-6).

Pennick, D.S., and W.W. Dimmick. 1997. Critique of the evolutionarily significant unit as a definition for "distinct population segments" under the U.S. Endangered Species Act. Conservation Biology 11: 611-619.

Phelps, S.R., B.M. Baker, P.L. Hulett, and S.A. Leider. 1994. Genetic analysis of Washington steelhead: Initial electrophoretic analysis of wild and hatchery steelhead and rainbow trout. Washington Department of Fish and Wildlife Report 94-9. Olympia, Washington.

Phelps, S., S.A. Leider, P. Hulett, B.M. Baker, and T. Johnson. 1997. Genetic analysis of Washington steelhead: preliminary results incorporating 36 new collections from 1995 through 1996. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Phelps, S. R., B.M. Baker, and C.A. Busack. 2000. Genetic relationships and stock structure of Yakima River basin and Klickitat River basin steelhead populations. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Pritchard, J.K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155: 954-959.

RASP (Regional Assessment of Supplementation Project). 1992. RASP summary report series. Part III. Planning guidelines. Bonneville Power Administration, Portland, Oregon.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* Simon, R.C., and P.A. Larkin, editors. The stock concept in Pacific salmon. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver, British Columbia.

Riddell, B. 1993. Spatial organization of Pacific Salmon: what to conserve? *In* Cloud, J.G., and G.H. Thorgaard, editors. Genetic conservation of salmonid fishes. Plenum Press, New York.

Saitou, N., and M. Nei. 1987. The neighbor-joining method: A new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4: 406-425.

Schuck, M. 1998. Washington's LSRCP trout program: 1982-1996. *In* Proceedings of the Lower Snake River Compensation Plan status review symposium, Doubletree Hotel Riverside, Boise, Idaho, February 3,4, and 5, 1998. Unpublished report by the U.S. Fish and Wildlife available at http://lsnakecomplan.fws.gov/Reports.

Snow, C. 2004. Annual progress report for Wells Hatchery summer steelhead, 2002 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Tonseth, M. A. Murdoch, T. Maitland, and T. Miller. 2004. Annual progress report for Wenatchee summer steelhead, 2002 brood. Unpublished report available from the Washington Department of Fish and Wildlife, Olympia, Washington.

Utter, F. 1998. Genetic problems of hatchery-reared progeny released into the wild, and how to deal with them. Bulletin of Marine Science 62: 623-640.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 48: 124-133.

Washington Department of Fish and Wildlife. 2003. Salmonid stock inventory (SaSI) 2002. Washington Department of Fish and Wildlife, Olympia, Washington.

Washington Department of Fisheries (WDF), Washington Department of Wildlife and Western Washington Treaty Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Washington Department of Fisheries, Olympia, Washington.

Whitesel, T.A., R.W. Carmichael, M.W. Flesher, and D.L. Eddy. 1998. Summer steelhead in the Grande Ronde River basin, Oregon. *In* Proceedings of the Lower Snake River Compensation Plan status review symposium, Doubletree Hotel Riverside, Boise, Idaho, February 3,4, and 5, 1998. Unpublished report by the U.S. Fish and Wildlife available at http://lsnakecomplan.fws.gov/Reports.

Personal Communications

Arterburn, J. Draft reports and data for sampling conducted in 2002 through 2004. Confederated Tribes of the Colville Reservation, Nespelem, Washington.

Kassler, T.W. and D.K. Hawkins. WDFW internal memorandum of June 14, 2005 to C. Kraemer and J. Tipping entitled "DNA Characterization of Steelhead in the Skykomish River".

McClure, M. and T. Cooney. NOAA Fisheries internal memorandum of May 11, 2005 to NMFS NW Regional Office, Co-managers, and Other Interested Parties entitled "Updated population delineation in the Interior Columbia Basin".

Schuck, M. WDFW internal memorandum of February 27, 2006 to B. Gill, A. Blakely, and B. Leland entitled "Steelhead White Paper Review".

Appendix 5-A. Methods for Genetic Analysis

Genetic analyses from external sources (ICTRT 2003; Myers et al. 2004) and WDFW were used to help identify steelhead populations. WDFW analyses were generally based on 156 collections of juveniles or adults collected from 1993 through 1996 (see Phelps et al. 1994; 1997). These investigators conducted horizontal starch-gel electrophoresis to analyze variation at 56 enzyme-coding loci using over 150 collections of adult or juvenile steelhead from throughout. Only sub-sets of data for Puget Sound, coastal Washington and the lower Columbia River populations were re-analyzed for this report. The 56 loci in the data set were: *mAAT-1; sAAT-1,2; sAAT-3; ADA-1; ADA-2; ADH; mAH-1; mAH-2; mAH-3; mAH-4; sAH; ALAT; CK-A1; CK-A2; CK-C1; CK-C2; FH; GAPDH-3; bGLUA; GPI-A; GPI-B1; GPI-B2; G3PDH-1; IDDH-1; IDDH-2; mIDHP-1; mIDHP-2; sIDHP-1,2; LDH-A1; IDH-B1; LDH-B2; LDH-C; sMDH-A1,2; sMDH-B1,2; ME; mMEP-1; sMEP-1; sMEP-2; MPI; NTP; PEPA; PEPB-1; PEPD-1; PEP-LT; PGK-2; PGM-1; PGM-1r; PGM-2; PNP; mSOD; sSOD-1;* and *TPI-3*.

Regional datasets were run through the program CONVERT v1.3 (Glaubitz 2003) to calculate allele frequencies for each collection and create input files for subsequent analyses using other programs. Genetic relationships among collections were explored using dendrogram analysis. Tools within the program PHYLIP v3.57 (Felsenstein 1989) were used to generate genetic distance matrices and dendrograms as indicated. SEQBOOT was used to generate multiple data sets that were resampled versions of each original input data set; 1000 bootstrapped data sets from the original allele frequency input file were created for each subset of steelhead collections (alleles were resampled with replacement to create new data sets with allele frequencies reflecting this resampling). GENDIST was used to compute pairwise Cavalli-Sforza and Edwards (1967) chord distances from the set of allele frequencies for each collection. For these analyses, 1000 Cavalli-Sforza and Edwards distance matrices (one for each bootstrapped data set) were created. The routine NEIGHBOR was used to implement the Neighbor-Joining (N-J) method of Saitou and Nei (1987) to construct a tree by successive clustering of OTUs (operational taxonomic units); 1000 dendrograms based on the distance matrices were thus created. CONSENSE was then used to create a consensus tree from the 1000 neighbor-joining dendrograms, including the bootstrap values for each of the nodes on the tree. These nodal bootstrap values represent the number of times the branching to the right of the node occurred in the 1000 trees analyzed for each data set. Trees were visualized, along with associated bootstrap values, using the TREEVIEW v.1.4 program (Page 1996). We considered bootstrap values of greater than 65% to indicate supported nodes and have deleted all lower bootstrap values (indicated nodes with little or no statistical support) to simplify the figures. The labeling of OTUs in the N-J dendrograms includes an abbreviation of the stream or hatchery (designated by 'H') name, the last two digits of the year of collection, and a one-letter code for the adult return time of the population ('S' =summer run; 'W' = winter run; or 'B' = possible mixed collection containing both summer and winter run fish).